

sheet (2)

D.C. Motor

- ① $P_{out} = 3.37 \text{ kW}$, $N_m = 1725 \text{ rpm}$, $V_a = 125 \text{ V}$, shunt, $\eta = 0.825$
at full load Req: ① P_{in} ② I_{line} ③ T_{out}

Solution

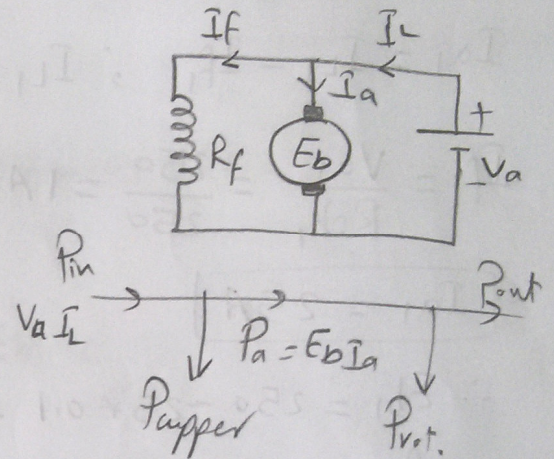
$$\eta = \frac{P_{out}}{P_{in}} \times 100 \quad \therefore 0.825 = \frac{3.37}{P_{in}}$$

$$\therefore P_{in} = 4.084 \text{ kW} \quad \#$$

$$P_{in} = V_a \cdot I_L$$

$$\therefore I_L = \frac{4084.848}{125} = 32.678 \text{ A} \quad \#$$

$$T_{out} = \frac{P_{out}}{\omega_m} = \frac{3.37 \times 10^3}{\left(\frac{\pi \times 1725}{30}\right)} = 18.655 \text{ N.m} \quad \#$$



- ② $V_a = 250 \text{ V}$, $R_a = 0.06 \Omega$ & $I_{a1} = 25 \text{ A} \rightarrow N_{m1} = 850 \text{ rpm}$, Series
 $I_{a2} = 18 \text{ A}$ Req: N_{m2} for $V_{a2} = V_{a1}$, $R_{se} = 0.025 \Omega$

Solution

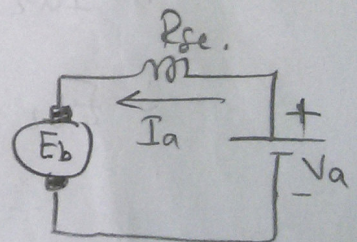
$$\begin{aligned} E_{b1} &= V_{a1} - I_{a1} (R_a + R_{se}) \\ &= 250 - 25 (0.06 + 0.025) \\ \therefore E_{b1} &= 247.875 \text{ V} \end{aligned}$$

$$\begin{aligned} E_{b2} &= V_{a2} - I_{a2} (R_a + R_{se}) \\ &= 250 - 18 (0.06 + 0.025) \\ \therefore E_{b2} &= 248.47 \text{ V} \end{aligned}$$

$\therefore E_b \propto I_f \omega_m \rightarrow$ for series motor $E_b \propto I_a \omega_m$

$$\therefore \frac{E_{b1}}{E_{b2}} = \frac{I_{a1} \cdot N_{m1}}{I_{a2} \cdot N_{m2}} \quad \therefore N_{m2} = \frac{I_{a1} E_{b2}}{I_{a2} E_{b1}}$$

$$\therefore N_{m2} = 1183.389 \text{ rpm} \quad \#$$



$R_a = 0.1 \Omega$, $N_{m1} = 1000 \text{ rpm}$, $250 = V_{a1}$ Shunt Motor, $R_{sh1} = 25 \Omega$
 $P_{i/p} = 6.5 \text{ Kw}$, if $V_{a2} = 230 \text{ V}$, $R_{sh2} = 125 \Omega$

Req: N_{m2} to keep $T_L = \text{const.}$

Solution

at $V_{a1} = 250 \text{ V}$

$$I_{a1} = I_{L1} - I_{f1}, \quad I_{L1} = \frac{P_{i/p}}{V_{a1}} = 26 \text{ A}$$

$$I_{f1} = \frac{V_{a1}}{R_{sh1}} = \frac{250}{25} = 1 \text{ A}$$

$$\boxed{I_{a1} = 25 \text{ A}}$$

$$\therefore E_{b1} = 250 - 25 \times 0.1 = 247.5 \text{ V}$$

for keeping T_L const., $T \propto I_f I_a$

$$\therefore \frac{T_{L1}}{T_{L2}} = \frac{I_{a1} I_{f1}}{I_{a2} I_{f2}} = 1$$

$$\therefore I_{f2} = \frac{V_{a2}}{R_{sh2}} = \frac{230}{125} = 1.84 \text{ A}$$

$$\therefore I_{a2} = I_{a1} \frac{I_{f1}}{I_{f2}} = \boxed{13.587 \text{ A}}$$

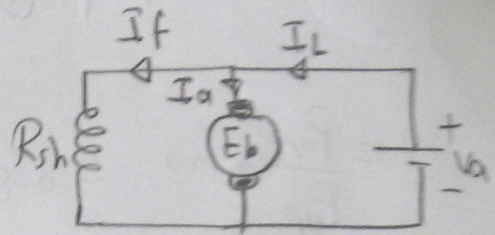
$$\therefore E_{b2} = 230 - 13.587 \times 0.1 = \boxed{228.6413 \text{ V}}$$

$\therefore E_b \propto I_f \omega_m$

$$\therefore N_{m2} = N_{m1} * \frac{E_{b2} I_{f1}}{E_{b1} I_{f2}}$$

$$\therefore \boxed{N_{m2} = 502 \text{ rpm}}$$

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series motor, $R_a = 0.1 \Omega$, $R_{se} = 0.05 \Omega$, $V_a = 600 \text{ V}$, $I_{a1} = 150 \text{ A}$
 $N_{m1} = 3000 \text{ rpm}$, $N_{m2} = 2000 \text{ rpm}$, R_{eq} , R_{add} series with armature
 To keep T_L const.

Solution

$$E_{b1} = V_{a1} - I_{a1} (R_a + R_{se})$$

$$\therefore E_{b1} = 600 - 150 (0.1 + 0.05)$$

$$\therefore \boxed{E_{b1} = 577.5 \text{ V}}$$

For T_L const. $\therefore T_L \propto I_a^2$ in series motor

$$\therefore I_{a1} = I_{a2}$$

$$\therefore \frac{E_{b1}}{E_{b2}} = \frac{N_{m1}}{N_{m2}} \quad \therefore E_{b2} = E_{b1} \frac{N_{m2}}{N_{m1}}$$

$$\therefore \boxed{E_{b2} = 385 \text{ V}}$$

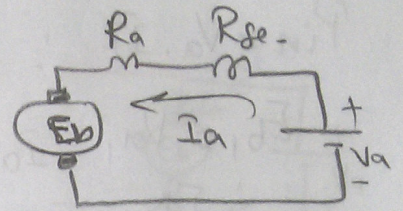
$$E_{b2} = V_a - I_{a2} (R_{add} + R_a + R_{se})$$

$$\therefore 385 = 600 - 150 (R_{add} + 0.15)$$

$$\therefore 215 = 150 (R_{add} + 0.15)$$

$$\therefore R_{add} + 0.15 = 1.433$$

$$\therefore \boxed{R_{add} = \cancel{0.2833} \Omega} \quad \#$$



⑤ Series $R_a = 0.1 \Omega$, $R_{fe} = 0.1 \Omega$, $N_m = 400 \text{ rpm}$, $P_{in} = 60 \text{ kW}$ at $V_{a1} = 500 \text{ V}$
 if $V_{a2} \rightarrow 400 \text{ V}$, $R_{ins} = 2.5$, $T_{L2} = \frac{1}{2} T_{L1}$ find $N_{m2} = ?$

Solutions

$$P_{in} = V_{a1} \cdot I_{L1} \therefore I_{L1} = I_{a1} = \frac{P_{in}}{V_{a1}} = \frac{60000}{500} = 120 \text{ A}$$

$$E_{b1} = V_{a1} - I_{a1} (R_a + R_{fe})$$

$$\therefore E_{b1} = 500 - 120 \times 0.2$$

$$\therefore \boxed{E_{b1} = 476 \text{ V}}$$

$\therefore R_{ins}$ inserted \therefore flux $\downarrow \downarrow \therefore I_{a1} \downarrow \downarrow$

$$\therefore T \propto I_a^2 \therefore \frac{T_{L1}}{T_{L2}} = \frac{I_{a1}^2}{I_{a2}^2}, T_{L2} = \frac{1}{2} T_{L1}$$

$$\therefore \frac{1}{2} = \frac{I_{a1}^2}{I_{a2}^2} \therefore I_{a2} = \sqrt{\frac{120^2}{2}} = \boxed{84.85 \text{ A}}$$

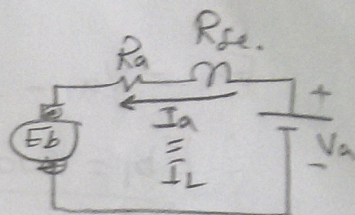
$$\therefore E_{b2} = V_{a2} - I_{a2} (R_a + R_{fe} + R_{ins})$$

$$\therefore E_{b2} = 400 - 84.85 (0.2 + 2.5)$$

$$\therefore \boxed{E_{b2} = 170.905 \text{ V}}$$

$$\therefore N_{m2} = N_{m1} \frac{E_{b2} I_{a1}}{E_{b1} I_{a2}}$$

$$\therefore \boxed{N_{m2} = 203.1127 \text{ rpm}} \#$$



$= 250 \text{ V}$, $R_{sh1} = 250 \Omega$, $R_a = 0.25 \Omega$, $N_{m1} = 1500 \text{ rpm}$, $I_{a1} = 20 \text{ A}$
 f $R_{sh2} = 500 \Omega$ $T_{L1} = T_{L2}$ Req: ① $N_{m2} = ?$ ② $I_{a2} = ?$

Solutions

$$E_{b1} = V_a - I_{a1} R_a = 250 - 20 \times 0.25$$

$$\therefore E_{b1} = 245 \text{ V}$$

$$I_{f1} = \frac{250}{250} = 1 \text{ A}$$

$$I_{f2} = \frac{250}{500} = 0.5 \text{ A}$$

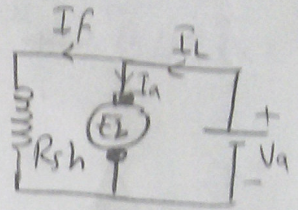
$$\therefore T_{L1} = T_{L2} \quad \therefore \frac{T_{L1}}{T_{L2}} = \frac{I_{f1} \cdot I_{a1}}{I_{f2} \cdot I_{a2}} \quad \therefore I_{a2} = I_{a1} \frac{I_{f1}}{I_{f2}} = \frac{1 \times 20}{0.5}$$

$$\therefore I_{a2} = 40 \text{ A}$$

$$\therefore E_{b2} = V_a - I_{a2} R_a = 250 - 40 \times 0.25$$

$$\therefore E_{b2} = 240 \text{ V}$$

$$\therefore N_{m2} = N_{m1} \times \frac{E_{b2} I_{f1}}{E_{b1} I_{f2}} = \frac{240 \times 1}{245 \times 0.5} \times 1500 = 2938.77 \text{ rpm}$$



⑦ $R_a = 0.1 \Omega$, $R_{sh} = 400 \Omega$, $V_a = 200 \text{ V}$ shunt, $I_{L1} = 10 \text{ A}$, $P_{rot.} = 100 \text{ W}$
 $N_m = 400 \text{ rpm}$ Req: ① P_a , ② P_{out} ③ η ④ T_{out}

Solutions

$$I_{f1} = \frac{V_a}{R_{sh}} = \frac{200}{400} = 0.5 \text{ A}$$

$$\therefore I_{a1} = 9.5 \text{ A} \quad \therefore E_{b1} = 200 - 9.5 \times 0.1 = 199.05 \text{ V}$$

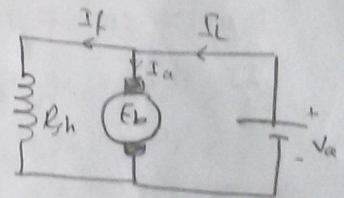
$$\therefore P_a = E_{b1} I_{a1} = 1.891 \text{ kW}$$

$$P_{in} = V_a I_{L1} = 2 \text{ kW}$$

$$\therefore P_{out} = P_a - P_{rot.} = 1.891 - 0.1 = 1.791 \text{ kW}$$

$$\therefore \eta = 89.55\%$$

$$T_{out} = \frac{P_{out}}{\omega_m} = \frac{1.791 \times 10^3}{\left(\frac{\pi \times 400}{30}\right)} = 42.756 \text{ N.m}$$



\rightarrow if $\phi_2 = \frac{1}{2} \phi_1$ $\therefore I_{f2} = \frac{1}{2} I_{f1}$, $I_{a2} = I_{a1}$, $V_{a2} = V_{a1}$

$$\therefore E_{b2} = E_{b1} = 199.05 \text{ V}$$

$$\therefore \frac{E_{b1}}{E_{b2}} = \frac{I_{f1} N_{m1}}{I_{f2} N_{m2}} \quad \therefore 1 = \frac{2 N_{m1}}{N_{m2}} \quad \therefore N_{m2} = 2 N_{m1} = 800 \text{ rpm}$$

if $T_{L2} = 2 T_{L1}$, $V_{a2} = V_{a1}$, $N_{m2} = ?$

⑦

$$\therefore T \propto I_f I_a \therefore \frac{T_{L1}}{T_{L2}} = \frac{I_{f1} I_{a1}}{I_{f2} I_{a2}}$$

→ Consider I_f const.

$$\therefore \frac{1}{2} = \frac{I_{a1}}{I_{a2}} \therefore I_{a2} = 2 I_{a1}$$

$$\boxed{I_{a2} = 19 A}$$

$$\therefore E_{b2} = 200 - 19 \times 0.1 = 198.1 V$$

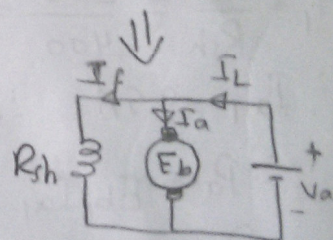
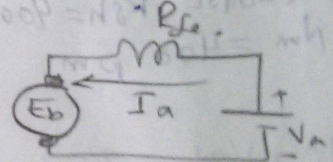
$$\therefore \frac{E_{b1}}{E_{b2}} = \frac{N_{m1}}{N_{m2}} \therefore N_{m2} = N_{m1} \frac{E_{b2}}{E_{b1}}$$

$$\therefore N_{m2} = 400 \times \frac{198.1}{199.05} = 398.1 \text{ rpm}$$

⑧ $P = 2$, $N_m = 707 \text{ rpm}$, $I_L = 100 A$, $V_a = 85 V$ series, $R_{se} = 0.03 \Omega$
 $R_a = 0.04 \Omega$ if become shunt $T_{L2} = T_{L1} \rightarrow N_{m2} = ?$

$$E_{b1} = V_a - I_{a1}(R_a + R_{se}) = 85 - 100 \times (0.03 + 0.04)$$

$$\therefore E_{b1} = 78 V$$



⑥

= 2 poles, $N_{m1} = 707 \text{ rpm}$, $I_{L1} = 100 \text{ A}$, $V_a = 85 \text{ V}$ with field coils in series (Two coils), $R_{se.} = 0.03 \Omega$, $R_a = 0.04 \Omega$
 → if field coils are parallel $\therefore (R_{se.} = \frac{0.03}{2} = 0.015 \Omega)$, $T_{L1} = T_{L2}$
 Req: ① $N_{m2} = ?$

② $R_{add} = ?$ to make speed = 707 rpm

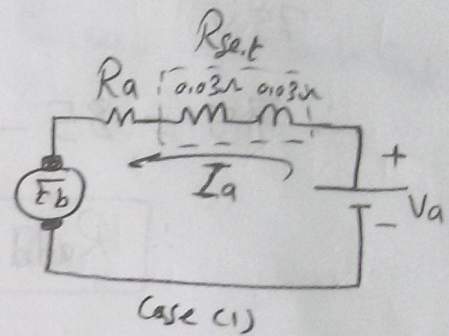
Solution

When the two field coils are connected in series $\therefore R_{set} = 0.03 + 0.03 = 0.06 \Omega$

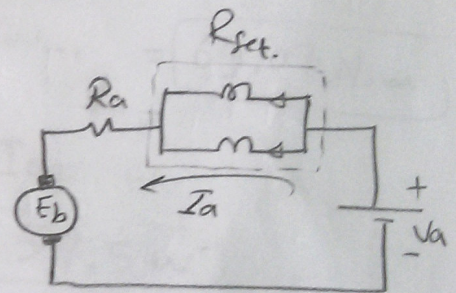
$$\therefore E_{b1} = V_a - I_{a1} (R_a + \overset{\text{series}}{R_{set}}) \quad , \quad I_{L1} = I_{a1}$$

$$\therefore E_{b1} = 85 - 100 * (0.04 + 0.06)$$

$$\therefore \boxed{E_{b1} = 75 \text{ V}}$$



When the two field coils are connected in parallel $\therefore R_{set.} = \frac{0.03}{2} = 0.015 \Omega$



the torque is constant

$$\therefore T \propto I_a^2 \text{ (series)} \quad \therefore \frac{T_1}{T_2} = \frac{I_{a1}^2}{I_{a2}^2} \quad \therefore I_{a1} = I_{a2} = 100 \text{ A}$$

تساوي التيار لأن التيار في سلكين على التوالي ويتجمع صوته أضعف (العزم ثابتاً)
 لأن توضع الملفات توالي لأنه التيار في سلكين على التوالي ويتجمع صوته أضعف (العزم ثابتاً)

$$\therefore E_{b2} = V_a - I_{a2} (R_a + \overset{\text{shunt}}{R_{set.}})$$

$$\therefore E_{b2} = 85 - 100 * (0.04 + 0.015) = \boxed{79.5 \text{ V}}$$

$$\therefore E \propto I_f \omega_m \quad \therefore \frac{E_{b1}}{E_{b2}} = \frac{I_{a1} N_{m1}}{I_{a2} N_{m2}} \quad \therefore N_{m2} = N_{m1} \frac{E_{b2}}{E_{b1}}$$

$$\therefore \boxed{N_{m2} = 749.42 \text{ rpm}}$$

$$\Phi = N I$$

تأثير المجال (تأثير المجال)
 تأثير التيار (تأثير التيار)

$R_{add} = ?$ to restore $N_m = 707 \text{ rpm}$?

$$\therefore N_{m2} = 749.42 \text{ rpm} \rightarrow E_{b2} = 79.5 \text{ V}$$

$$\therefore E_b = V_a - I_a (R_a + R_{set}) \rightarrow 707 \text{ rpm}$$

shunt

$$75 \text{ V}$$

$$\therefore 75 = 85 - 100 \times (0.04 + R_{add} + 0.015)$$

$$\therefore R_{add} = 0.045 \Omega$$

ies, $V_a = 440 \text{ V}$, $R_a + R_{se} = 0.3 \Omega$

$R = 0 \Omega$

$I_{a1} = 20 \text{ A}$, $N_{m1} = 1200 \text{ rpm}$
at $R = 3 \Omega$

$I_{a2} = 15 \text{ A}$ $\textcircled{1}$ $N_{m2} = ?$

② if $\Phi_1 = 8 \text{ mwb}$, find $P_a = E_a I_a$, $T_a = P_a / \omega_m$ in each case?

Solution

at $R = 0 \Omega$

$$E_{b1} = V_a - I_{a1}(R_a + R_{se} + R_{\text{go}})$$

$$\therefore E_{b1} = 440 - 20(0.3)$$

$$\therefore \boxed{E_{b1} = 434 \text{ V}}$$

at $R = 3 \Omega$

$$E_{b2} = V_a - I_{a2}(R_a + R_{se} + R_{\text{go}})$$

$$\therefore E_{b2} = 440 - 15(0.3 + 3)$$

$$\therefore \boxed{E_{b2} = 390.5 \text{ V}}$$

$\therefore E_b \propto I_f \omega_m$ \uparrow series $\therefore E_b \propto I_a \omega_m$

$$\therefore \frac{E_{b1}}{E_{b2}} = \frac{I_{f1} N_{m1}}{I_{f2} N_{m2}}$$

$$\therefore \frac{434}{390.5} = \frac{20 \times 1200}{15 \times N_{m2}}$$

$$\therefore \boxed{N_{m2} = 1439.63 \text{ rpm}}$$

$$P_{a1} = E_{b1} \cdot I_{a1}$$

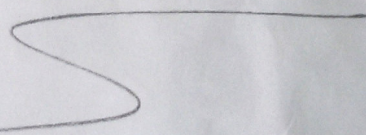
$$\therefore \boxed{P_{a1} = 8680 \text{ W}}$$

$$\therefore T_{a1} = P_{a1} / \omega_{m1} = \boxed{69.07 \text{ N.m}}$$

$$P_{a2} = E_{b2} \cdot I_{a2}$$

$$\therefore \boxed{P_{a2} = 5857.5 \text{ W}}$$

$$\therefore T_{a2} = P_{a2} / \omega_{m2} = \boxed{38.853 \text{ N.m}}$$



⑩ shunt, $N_{m1} = 1200 \text{ rpm}$, $V_a = 420 \text{ V}$, $I_{a1} = 30 \text{ A}$, $R_{add} = ?$
 $N_{m2} = 600 \text{ rpm}$, $I_{a1} = I_{a2}$, $R_a = 3 \Omega$?

Solutions

$$E_{b1} = V_a - I_{a1} R_a = 420 - 30 \times 3 = 330 \text{ V}$$

$$\therefore E \propto I_f \omega_m$$

$$I_f = \text{Constant}$$

$$\therefore \frac{E_{b1}}{E_{b2}} = \frac{N_{m1}}{N_{m2}} = \frac{1200}{600}$$

$$\therefore E_{b1} = 2 E_{b2} \therefore E_{b2} = \frac{1}{2} E_{b1} = 165 \text{ V}$$

$$\therefore \boxed{E_{b2} = 165 \text{ V}}$$

$$\therefore E_{b2} = V_a - I_{a2} (R_a + R_{add})$$

$$\therefore 165 = 420 - 30 (3 + R_{add})$$

$$8.5 = 3 + R_{add}$$

$$\therefore \boxed{R_{add} = 5.5 \Omega}$$